CONF-791051--20

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Status Report on Activities of ASTM E10.05.01 Task Group on Uncertainty Analysis

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Research sponsored by Division of Reactor Safety Research U. S. Nuclear Regulatory Commission under Interagency Agreement DOE 40-551-75 with the U. S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.

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The ASTM E10.05.01 Task Group was formed at the December 1978 meeting of the ASTM E10.05 Subcommittee meeting. It was charged with providing guidance in determining and applying uncertainties in the field of reactor dosimetry.

It was decided at the first meeting to conduct a survey on uncertainty analysis as it is practiced at leading laboratories, which are involved in reactor dosimetry. Subsequently, a questionnaire was prepared and mailed to about 45 installations and researchers. Nine replies were received, several of them were prepared by more than one author. Three of the nine came from installations outside the U.S.A.

Although few in number, the replies covered a good cross section of the field. There was little, if any, disagreement between the participants. Uncertainty analysis is well established in some areas, for instance, gamma counting in foil detectors, whereas little attention has been given to other, more difficult problems, like uncertainties in neutron transport calculations. From the replies it becomes clear that more work in these areas is needed to obtain reliable and consistent uncertainty estimates in field like radiation damage analysis.

A summary of the replies was presented at a meeting of the Task Force on May 21, 1979, and is attached for this report. This summary provides a fairly complete list of the different aspects of uncertainty analysis in reactor dosimetry, but cannot do complete justice to the many detailed and thoughtful presentations contained in the individual replies.

At a subsequent meeting on May 23, 1979 the following topics were discussed concerning future actions of the Task Group:

1. There is a need for guidance in the determination and use of covariances and correlations. Recently developed adjustment

codes like STAYSL require the complete covariance matrix as input. Many researchers feel that the consideration of covariances is not justified if overall uncertainties are large. The question arises, whether STAYSL can be applied in these cases and how to proceed.

No immediate action was taken, but it was pointed out that the Task Group could publish guidelines concerning uncertainty analysis in the "gray pages" of the annual ASTM Standards whenever development of new standards would be either too slow or controversial.

2. There is a need to obtain a better understanding of the uncertainties in the dosimetry of commercial power reactors. Estimates of uncertainties can be obtained with relative ease in the well controlled environment of research reactors. However, results from research reactors cannot be transferred to commercial reactors unless the parameters which affect their operation are better known. For this purpose S. L. Anderson, G. L. Simmons, and H. H. Till agreed to provide a review of uncertainties in commercial power reactors for the next meeting of the Task Group.

Summary of the ASTM E10.05.01 Survey on Uncertainty Analysis

<u>Question 1</u>

What are the most significant considerations in dealing with experimental and computational errors? What are the problem areas which require special attention?

<u>Three Types of Errors Encountered in Dosimetry</u>

1. Experimental
2. Nuclear Data
3. Computational

<u>Experimental Errors</u>

1. Irradiation Fields:
   a. Uncertainties due to flux gradients
   b. Field perturbations
   c. Shielding effects
2. Radiation Measurements
   a. Counting efficiency, deadtime corrections, etc.

<u>Nuclear Data</u>

1. Cross Sections
   a. Reaction cross section, shielding cross sections, relations between point and integral data
2. Others
   a. Decay schemes, fission yields, etc.

<u>Computational Errors</u>

1. Input Spectral
   (Uncertainties due to cross sections, fission spectra, modeling)
2. Unfolding Methods
3. Error Propagation Schemes

Question 2

How much effort is justified to obtain the best error bounds and where should this effort primarily be spent?

Quality Control

Purity of Materials

Selection of Best Equipment

Consistency in Evaluation Methods

Complete List of Error Sources

Special attention should be given to sources of errors which contribute most to the overall uncertainty. (Cross section and input spectrum uncertainties are mentioned prominently as major contributors.)

Question 3

How should uncertainties (error bounds) be assigned in cases where no clear-cut statistical methods are applicable (e.g., calibration errors or modeling errors)?

This question is meant to address the problems associated with the so-called "systematic errors". These are very difficult problems and there are no clear-cut procedures for dealing with these uncertainties. It is interesting to note that a year ago the International Committee of Weights and Measures created a study group and distributed a questionnaire which deals almost exclusively with systematic errors.

The problems associated with systematic errors fall into two broad categories. The first one concerns procedures to assign reliably numerical values to these uncertainties. The second one is to assign appropriate statistical distributions to systematic errors in order to combine them with each other and with random errors of other types. What follows is a condensed form of the suggestions made by the participants in this survey.

Numerical Values

1. Educated Guesses
2. Sensitivity Studies
3. Benchmark Testing

Probability Distribution

(As model for error propagation)

1. Gaussian (Central limit theorem invoked)
2. Flat Distribution within Bounds
3. Correlations (Systematic errors are common to sets of several measurements. The resulting covariances must be considered.)

Question 4

How should uncertainties from diverse sources be combined? In particular, if errors are not independent, how should correlations(covariances) be assigned and used?

Covariances Need to be Considered in Combining Uncertainties

1. Identify sources of uncertainties which are common to several measurements.
2. Replace scalar algebra with matrix algebra in combining uncertainties.

Question 5

How should uncertainties be assigned to quantities which are not single numbers, but a function of another quantity like cross sections or neutron spectra?

This question was left unanswered by most participants. Since this is an important problem I would like to insert some comments on my own. There exists an elaborate statistical theory which deals with random functions, namely the theory of stochastic processes. However it is well to remember that functions are never directly observed but are a mathematical abstraction describing a particular model. All quantities of interest whether observed or calculated are integrals over these functions. Typically certain integral quantities are measured, e.g., reaction rates from a set of foil detectors, to determine the point function, say the neutron spectrum. This in turn is then used to obtain another integral quantity, e.g., the damage integral for steel.

In terms of uncertainty analysis all that is needed - and indeed all that is possible to know - are the correlations between the measured integral quantities and the output quantities we want to predict. These correlations - with associated uncertainties - appear as parameters in the essentially unknown black box model. Using a combination of experimental evidence and reasoning based on physical models correlations between different integral quantities can be established directly including the associated covariances matrix.

It is, or course, possible to assign uncertainties and covariances to functions. However this approach is fraught with mathematical pitfalls and unproven physical assumptions which can be avoided by the direct method.

Question 6

How should uncertainties be documented in publications and data banks, in particular, for those quantities which will be used in critical applications like cross-section files?

Documentation Should be Standardized

A reference document on reporting uncertainties should be developed.

Two Forms of Reporting Uncertainties

(Not mutually exclusive)

1. Document variances (standard deviations) and covariances (correlations)
2. Document confidence levels (percent confidence bounds, one sigma, two sigma, variance times student factor)

Question 7

What services should the task force on uncertainty analysis perform?

1. Motivate metrologists to provide a detailed inventory of uncertainties and their correlation.

2. Set standards for uncertainty analysis.
   a. Inventory
   b. Estimation
   c. Propagation
   d. Documentation